ANNALS of Faculty Engineering Hunedoara – International Journal of Engineering

Tome XII [2014] – Fascicule 3 [August]
ISSN: 1584-2673 [CD-Rom, online]

a free-access multidisciplinary publication of the Faculty of Engineering Hunedoara

[1.] Sándor BESZÉDES, [2.] Petra VESZELOVSZKI, [3.] Lajos LUDÁNYI, [4.] Gábor KESZTHELYI-SZABÓ, [5.] Cecilia HODÚR

CORRELATION BETWEEN DIELECTRIC PARAMETERS AND BIODEGRADABILITY OF MEAT PROCESSING SLUDGE

[1,3-5.] Department of Process Engineering, Faculty of Engineering, University of Szeged, Szeged, Moszkvai krt.9, HUNGARY

[2.] Technical Institute, Faculty of Engineering, University of Szeged, Szeged, Moszkvai krt.9, HUNGARY

Abstract: Thermal and athermal effects of microwave irradiation can change the structure of bio-materials but the dielectric properties of processed material have also effects on the heat transfer simultaneously. The relationship between the dielectric parameters and the disintegration degree or the biodegradability has not been investigated for wastewater sludge yet. Therefore our experimental work was focused on the measurement of dielectric properties of sludge originated from meat processing wastewater, furthermore the relationship and correlation between the parameters related to the organic matter solubility, biodegradability and the dielectric parameters, such as the dielectric constant and dielectric loss factor were also analyzed. Experimental results have verified that during MW processing the structure of wastewater sludge has been efficiently disintegrated, this effect was manifested in an increased migration ability of ions liberated from the polymeric matrix of sludge and from intracellular components. These structural changes have led to increased value of dielectric constant and loss factor. The temperature depending change of disintegration degree of sludge has a good correlation with dielectric loss factor and biodegradability, characterized by the ratio of biochemical to chemical oxygen demand.
Keywords: sludge, biodegradability, microwave, dielectric parameters

1. INTRODUCTION

Professionals in food industry companies face the high disposal costs of bio-wastes and the rising price of energy sources. Nowadays the renewable energy generation can be often connected to waste management technologies (László et al., 2007). For example, since an effective utilization of food industrial biomass waste has desired, the establishment and optimization of an efficient biogas production process from these waste materials is very important from perspectives of both energy and environmental issues (Kalmár et al., 2010).Food industry generates a huge amount of liquid and solid organic waste and by-products. Beside the considerable environmental risk of waste, it has a good potential to indirect bio-energy production for example in anaerobic digestion (AD) process. Biofuel production from agri-food wastes can also contribute to make waste management more socially acceptable, sustainable and cost effective (Nagy and Farkas, 2013).

Some pre-treatments assist or accelerate the hydrolysis of macromolecules or enhanced volatilization. Among pre-treatments, microwave irradiation alone or combined it with other thermal and chemical methods is considered as an intensive process with short process time and good ability to enhance the disintegration of sludge flocks and to accelerate the biological degradation of organic materials (Leonelli and Mason, 2010). Application of MW irradiation combining with the oxidation process, such as ozonation, can also be considered to be promising technology as pre-treatment before AD of high organic matter containing but less degradable sludge (Beszédes et al., 2009). Energy transfer carried by microwave irradiation affect the biodegradability of materials in two ways. Thermal effect is expressed in the increase of internal pressure of intracellular liquor caused by internal heating and rapid evaporation, which altogether can lead to cell wall disruption (Géczi et al., 2013). The non-thermal effect of high frequency electromagnetic field contributes to alter the structure of macromolecules with polarization of side chains and breaking of hydrogen bounds (Park et al., 2004; Lakatos et al., 2005).High efficiency of MW treatments in the biomaterial processing and also on the rate of chemical reactions is often explained by the non-thermal effects of microwaves due to the direct interaction of electromagnetic field with molecules (Szerencsi et al., 2009).

Thermal and a-thermal effects of the microwave (MW) irradiation play role in the “hot-spot” overheating phenomena, and the different dielectric parameter of cell components led to selective heating manifested in the different thermal stress, which contributes in the intensive degradation of cell wall components such as cellulose and pectin (Banik et al., 2003). MW pre-treatment has verified positive effects on cell wall destruction and releasing of organic matter into the soluble phase, but combining of it with addition of chemicals such as alkali, acid and oxidizer agents cause synergetic mechanism to accelerate the decomposition under aerobic and anaerobic condition., as well (Beszédes et al., 2011).The dielectric properties, namely the dielectric constant (ε’) and the dielectric loss factor (ε”) are important for predicting the behavior of materials during microwave processing, because both of them determine the interaction between the molecules with the oscillating electromagnetic field (Géczi et al., 2013). Dielectric constant measure the ability of material to store the irradiated energy, the value loss factor relate to the ability of material to convert electric energy into heat (Zheng et al., 2009).

The most of MW application aim the rapid heat generation, therefore influence of temperature on the dielectric parameters was one of the main key issues of microwave research. Dielectric constant of sludge decreases with increasing temperature, as well as the dielectric loss factor. Contrary to the MW drying process of solid biomaterials, penetration depth is not changed in a wide temperature range under 100°C during sludge processing, what do not decrease the energetic efficiency of the MW operation.

2. MATERIALS AND METHODS

Investigated wastewater sludge was originated from meat industry with a total solid (TS) content of 9.7%, initial total COD of 105.9 kgm^{-3}, and soluble COD of 20.1 kgm^{-3}. The chemical oxygen demand of sample was measured triplicated using colorimetric standard method (APHA, 2005). COD in supernatant was determined after separation by centrifugation (12,000 rpm for 10 minutes) and prefiltration (0.45 μm Millipore disc filter). The biochemical oxygen demand (BOD_5) measurements were carried out in a respirometric BOD meter (BOD Oxidirect, Lovibond, Germany), at 20 °C for 5 days.

Dielectric constant (ε’) and dielectric loss factor (ε”) were determined in a tailor made dielectrometer equipped with a dual channel NRVD power meter (Rohde & Schwarz). Magnetron of dielectrometer operates at a frequency of 2450 MHz. ε’ and ε” was calculated from the reflection coefficient phase shift, incident and reflected power.

3. RESULTS AND DISCUSSION

In the first series of our experiments the dielectric constant (ε’), the dielectric loss factor (ε”) and temperature dependency of them were determined. For the analysis two sludge sample were used with different dry matter content (SL1=9,7 w%; and SL2=14,8 w%). SL2 sludge was prepared from SL1 sludge by addition of concentrated sludge fraction to achieve higher dry matter content. The temperature range of measurements was 20-80˚C to avoid boiling, because bubbles containing vapor disturb the analysis of dielectric parameters in the measuring cell of dielectrometer used in our experiment. Fluctuation of dielectric parameters can occur when boiling point is reached during the heating, or air bubbles are arisen in the fluid.

Our experimental results show, that despite of the high moisture content of sludge, temperature depending behavior of ε’ was different that of can be known for water. SL1 sludge had a decreasing tendency in the temperature range of 20-60˚C, but over a critical value of the temperature increasing induced an increment in the value of ε' (Figure 1). SL2 sludge with higher dry matter content had a different behavior as a function of temperature, because over the temperature of 60˚C increment of ε' was not significant. Change of dielectric loss factor, as the function of temperature, has a similar tendency to ε' for SL1 sludge. Contrary to the different behavior of ε', tendency of the change in the value of ε" for SL1 was similar to that of measured for SL2 (Figure 2). The temperature depending breaking point for ε" was different for the two type of sludge with different dry matter content.

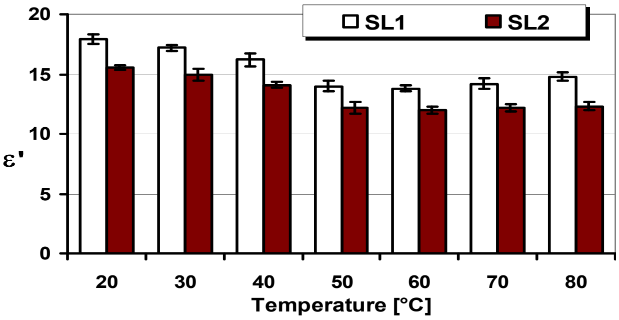

Figure 1. Dielectric constant (ε') of SL1 and SL2 sludge samples at different temperature

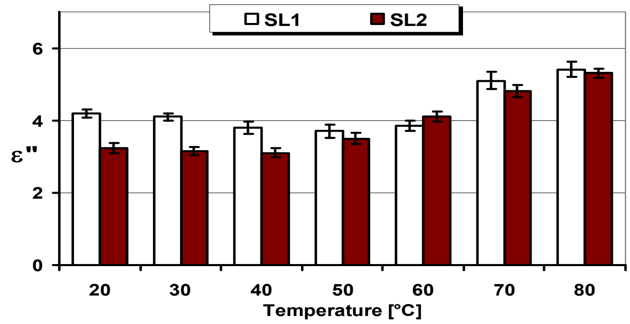

Figure 2. Dielectric loss factor (ε") for SL1 and SL2 sludge

After decreasing phase the value of ε" starts to increase at 50˚C and 40˚C for SL1 and SL2 sludge, respectively. Therefore, it can be concluded, that the value of dielectric loss factor was influenced by the temperature moisture content of sludge, as well. Because the quantity of sample and the water content was not changed during the measurement the special behavior of ε" was assumed to the structural change of sludge.

In order to find explanation for the change of ε" and to confirm our hypothesis on structural change, in other experimental series the ratio of soluble chemical oxygen demand (sCOD) to the total chemical oxygen demand (tCOD) was determined, which correlate the disintegration degree and the solubility of sludge organic matters. Our experimental results verified that the change of sCOD/tCOD has a good linear correlation with the dielectric loss factor (Figure 3).

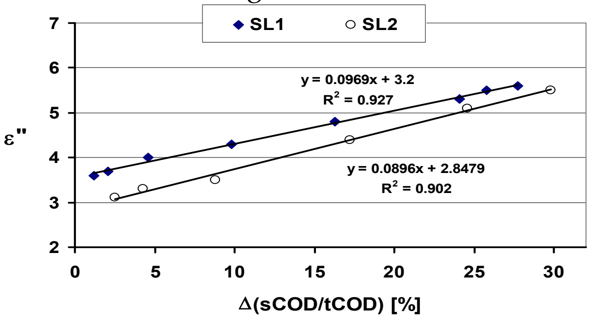

Figure 3. Relationship between solubility of organic matter and ε"

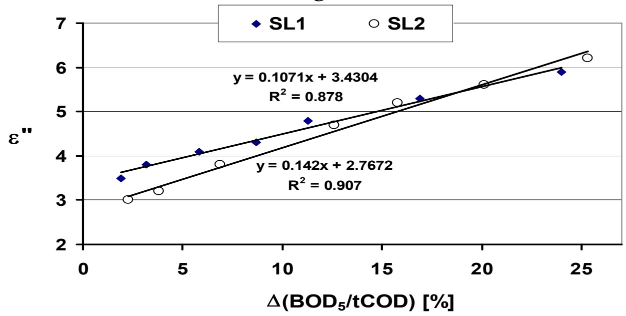

Figure 4. Correlation between the biodegradability and dielectric loss factor

The thermal treatments resulted in the disruption of cell wall and disintegration of sludge structure what has an increasing effect of the ratio of fee water content to the bounded water in the sludge. On the other hand, the degraded cell walls led to the liberation of intracellular substances and the hydrolysis of macromolecules resulted in a higher concentration and enhanced migration ability of ions and polar compounds. Above a certain temperature, when sludge disintegration reach a critical value, the change of dielectric parameters are more influenced by the ionic migration than the dipole rotation (Leonelli and Mason, 2010).

On the other hand, the change in solubility of organic matter has also effect on biodegradability. The correlation between solubility and biodegradability given as the ratio of BOD to COD has been verified earlier (Beszédes et al., 2009). Similar to the trends for the solubility change, a good correlation was found between the dielectric loss factor and the change of biodegradability measured by the BOD/tCOD parameter (Figure 4).

Because the biodegradability is linked to the solubility of organic matter content of sludge, the change of BOD_5/tCOD parameter show similar trends that of obtained from sCOD/tCOD analysis. The measurement of dielectric parameters, mainly the dielectric loss factor (ε"), provide an in-line feasibility for estimation the change in biodegradability and the efficiency of sludge disintegration during the microwave sludge conditioning process.

4. CONCLUSION

In our work the dielectric constant (ε') and the dielectric loss factor (ε") was measured for a meat processing wastewater sludge. There was found, that ε' and ε" decreasing with increasing temperature, but over a certain value of temperature (depending on the dry matter content of sludge) start to increase. This behavior of dielectric parameters is in a relationship with the structural change of sludge, which was characterized by the sCOD/tCOD ratio and the biodegradability of organic matter content of sludge, which was given by the ratio of BOD_5 to tCOD. Our experimental results verified that the change in the value of dielectric loss factor correlate with the disintegration degree and the biodegradability of sludge, as well Correlation between the electrical parameters and biodegradability indicators enable to develop a real-time and in-line measuring and control system for batch and continuous flow microwave sludge conditioning technology.

Acknowledgments

The research work of the first author, Sándor Beszédes, was supported by the European Union and the State of Hungary, co-financed by the European Social Fund in the framework of TÁMOP-4.2.4.A/ 2-11/1-2012-0001 'National Excellence Program' (A2-JÁDJ-13-003). The members of research group are thankful for the financial support provided by the Hungarian Scientific Research Fund (OTKA), under contract number K105021.

REFERENCES

[1.] Banik, S., Bandyopadhyay, S., Ganguly, S. (2003): Bio-effects of microwave-a brief review. Bioresource Technology, 2003:87, 155-159 p.

[2.] Beszédes, S., László, Zs., Szabó, G., Hodúr C. (2009): Examination of the effect of microwave irradiation on the biodegradable and soluble fraction of organic matter of sludge. Annals of Faculty of Engineering Hunedoara-International Journal of Engineering, 2009: 7(4), 87-90 p.

[3.] Beszédes, S., László, Zs., Szabó, G., Hodúr C. (2011): Effects of microwave pretreatments on the anaerobic digestion of food industrial sewage sludge. Environmental Progress and Sustainable Energy, 2011:30, 486-492 p.

[4.] Géczi G., Horváth M., Kaszab T., Alemany G.G. (2013): No majdor differences found between the effects of microwave-based and conventional heat treatment methods on two different liquid foods. PLOS ONE 2013:8(1), 1-12p.

[5.] Kalmár, I., Kalmár, V.E., Farkas, F., Nagy V. (2010): Energy naturally - biogas and biodiesel. Review Of Faculty of Engineering, Analecta Technica Szegedinensia, 2010:2-3, 122-127 p.

[6.] Lakatos, E., Kovács, AJ., Neményi, M. (2005): Homogenious microwave field creation. Hungarian Agricultural Engineering, 2005:18, 80-81 p.

[7.] László, Zs., Beszédes, S., Kertész, Sz., Hodúr, C., Szabó, G., Kiricsi I. (2007): Bioethanol from sweet sorghum. Hungarian agricultural Engineering, 2007:20; pp. 15-17

[8.] Leonelli C., Mason T.J. (2010): Microwave and ultrasonic processing: Now a realistic option for industry. Chemical Engineering and Processing, 2010:49, 885-900 p.

[9.] Nagy V, Farkas F. (2013): Emission testing used biogas and vegetable oils as fuels. Acta Technica Corviniensis – Bulletin of Engineering, 2013:6(1); pp. 129-132.

[10.] Park, B., Ahn, J.H., Kim, J., Hwang, S. (2004): Use of microwave pretreatment for enhanced anaerobiosis of secondary sludge. Water Science and Technology, 2004:50, 17-23 p.

[11.] Zheng, J., Kennedy, K.J., Eskicioglu C. (2009): Effect of low temperature microwave pretreatment on characteristic and mesophilic digestion of primary sludge. Environmental Technology, 2009:30, 319-327 p.